

Bay Inhabitants Are Mostly Aliens

By WILLIAM K. STEVENS

BERKELEY, Calif.

From the vantage point of the Berkeley Marina one recent morning, San Francisco stood sharply etched against a fog bank nestling along the Pacific shore like a gigantic roll of cotton candy, a recurring tableau essentially unchanged since Tony Bennett first left his heart in the city across the bay.

But ecologically speaking, the broad, aquamarine expanse of San Francisco Bay itself has been drastically reinvented.

Every 12 weeks on average, a new species of aquatic animal, plant or microbe from somewhere else in the world takes up residence in the bay. It has become what one expert, Dr. James T. Carlton of the Williams College Maritime Studies Program at Mystic, Conn., calls "an accidental zoo" — a churning, chaotic cauldron of life in which scores of weird, wonderful creatures of ancient lineage that "never before met each other until just a moment ago in ecological time" have been thrown together.

So far as is known, ecologists say, the bay is the estuary most invaded by exotic species in the world, and estuaries in general are the earth's most invaded marine ecosystems.

On that recent morning, Dr. Andrew N. Cohen, a marine biologist at the University of California at Berkeley who works closely with Dr. Carlton, directed a visitor's attention to an especially revealing gauge.

It was a block of orange Styrofoam, perhaps 3.5 feet by 1.5 feet, of the type that buoys the floating docks of Berkeley and other marinas. When lifted from the water, the block's underside appeared covered by a mass of multicolored moss and lettuce, black, brown, green, tan and yellow. But the plantlike organisms were actually colonies of marine animals, among them sponges and sea squirts, that cling to underwater surfaces around the bay in great masses. About a dozen species were visible, and invisible, uncounted microorganisms raised the total considerably.

"Virtually everything you see has arrived in San Francisco Bay from some other part of the world," Dr. Cohen said. That is the way it is the length and breadth of the bay's food web, from top predators like striped bass (introduced on purpose from the Atlantic Ocean more than a century ago) to microscopic protozoa from Japan.

Invasive species are seen almost everywhere in the world as human activity persistently rearranges the earth's flora and fauna. But San Francisco Bay offers a special window on where the global game of mix and match is leading at its most extreme. Species from other oceans now dominate the bay, and more are being crammed in all the time. They cover the bay's bottom virtually wall to wall, and no part of the larger bay ecosystem has escaped their impact; in some places they

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One to Watch: Chinese Mitten Crab

First identified in San Francisco Bay two years ago, the Chinese mitten crab has sometimes swarmed alarmingly in other invaded territories, even walking into houses in Germany.



Illustration by Deborah Ross for The New York Times

A cauldron of
organisms, all
strangers in
ecological time.

San Francisco Bay Teems with Alien Species

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appear to account for all life.

They have, in fact, created a brand new ecosystem and perhaps, in time, will write a new chapter in evolution.

These exotic invaders (scientists have identified 212 such species so far, and the origins of 123 others are unknown) have arrived by a variety of avenues, from piggybacking on imported oysters to deliberate introduction to hitchhiking in boxes of fish bait. But the biggest single mechanism, scientists believe, is the ballast water from ships. Discharged routinely and daily into the bay in larger quantities from bigger vessels, ballast water is believed to have caused a marked acceleration of the invasion in the last decade.

Continuing invasions are changing the ecosystem so fast that scientists are doing well just to keep up with the growing inventory and distribution of species. Understanding the organisms' interactions and the characteristics of the new system has proved more elusive. Each new introduced species "can send it off in a different direction," Dr. Carlton said of the ecosystem, "and because I don't know what my next species is tomorrow, I don't know what to predict."

Ecologists like Dr. Cohen and Dr. Carlton, the authors of an exhaustive study of the bay this year for the United States Fish and Wildlife Service, know that there are both positive and negative effects. For openers, there are many more species in the bay than before the invasions; the rich new ecosystem is in some measure a showcase of life's inventive variety.

But similar groupings of species are also being assembled in other estuaries around the globe while the bay's native flora and fauna dwindle in the face of the invasion from abroad. At least one bay species, the thicktail chub, has been driven to extinction. Another, the delta smelt, is endangered. A third, the Sacramento perch, can no longer be found in local waters. And many other native populations have been diminished. Invading predators may have contributed to the losses, Dr. Cohen said.

The bay has "lost the distinctive faunal characteristics and the web of community relationships that it had developed since its post-ice age origin, and which distinguished it from the other great estuaries of the world," the two ecologists wrote in a report last year.

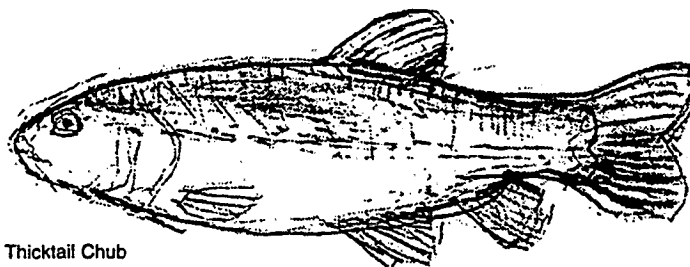
While the worldwide conveyor belt has transferred at least a handful of San Francisco Bay species to distant



Darcy Padilla for The New York Times

Dr. Andrew N. Cohen, a marine biologist at the University of California, examining an exotic marine growth.

Some of the Bay's Winners and Losers



Thicktail Chub



Burrowing Isopod

The native thicktail chub has been wiped out. The burrowing isopod, *Sphaeroma pentodon*, originally from New Zealand, Tasmania and Australia, which arrived in 1893, commonly burrows into any soft material, including styrofoam floats.

Source: Dr. Andrew W. Cohen.

Illustrations by Deborah Ross for The New York Times

A bay offers a special window on the global game of mix and match.

estuaries, Dr. Cohen said, the extent and volume of the outbound transfer are not known. For terrestrial species, the flow is heavily from Europe and Asia to other parts of the world. For estuarine species, he said, "we don't have a handle on the preponderance one way or the other."

For good or ill, signs of the bay's transformation are everywhere.

"Oh, yes, all right!" Dr. Cohen exclaimed as he examined a tiny isopod, similar to the American pillbug that rolls up into a ball, that he had just extracted from a glob of biological material clinging to a dock at the Coast Guard station in Oakland. Dr. Cohen's excitement was the scientist's excitement over discovery, in this case directed at a recent arrival of Australian origin. But some of the isopod's relatives appear to be boring into and severely damaging the Styrofoam underpinnings of some docks, causing them to sink slowly.

At an arm of the bay within sight of the Oakland Coliseum, littleneck clams from Japan, exposed at low

tide, cover the mud like smooth, gray stones. Some people harvest and eat them.

On Bay Farm Island, ribbed horse mussels, natives of the Atlantic, burrow into the mud between the low and high tide marks. They are in the bay by the millions, forming dense colonies. On Bay Farm Island, they bury themselves with just the tips of their double shells exposed and slightly separated. Scientists say they often clamp shut on the toes or bills of the endangered California clapper rail, sometimes causing adult birds to starve and chicks to drown. On the other hand, the mussels have become the rails' main food.

The rails' life is made further hazardous by two introduced land predators, the Norway rat and the red fox. Some measure of refuge from them has been provided by yet another aquatic invader — Atlantic cordgrass, which thickly covers the shore of Bay Farm Island with a tall, thick protective blanket. But whether it is better habitat than the sparser Pacific cordgrass it is replacing is not known. Nor is it clear just how all of this ecological pulling and hauling will ultimately affect the endangered bird.

Farther south, on the bay shore near Hayward, Dr. Cohen reaches down with a long-handled net and brings up a haul of what look like black-eyed peas. They are tiny Asian clams, invaders that have covered large stretches of the bay's bottom at a peak density of more than 4,000 a square foot since their introduction a mere decade ago, probably as larvae in ballast water.

The clams are too small to have



Alien species have already altered the San Francisco Bay ecology.

any economic value, but their effect on the life of the bay is enormous. They subsist on microscopic animals and plants, called zooplankton and phytoplankton, which form the basis of the bay's food chain. Scientists calculate that in the northern bay, where the clams are particularly dense, they can filter plankton from all the water in the deep channels more than once a day and all the water in the shallows, where phytoplankton especially abound, nearly 13 times a day. It is feared that the clams will permanently reduce the plankton, to the detriment of fish that feed in open water.

Another recent arrival from Asia, the Chinese mitten crab, so called because of its hairy claws, conjures fears of another sort. A native of Korea and China, it may have been planted in the bay as a food source. But its behavior when introduced outside its native range has sometimes been disturbing. In Germany in the 1930's, Dr. Cohen and Dr. Carlton wrote in their report, the invading crabs became "phenomenally abundant," with masses of them "migrating up the main rivers, piling up against dams, climbing spillways and swarming over the banks onto shore, sometimes wandering onto city streets and entering houses." No such onslaught has yet taken place here, but the crabs were first identified in the bay only two years ago.

An arrival in the late 1980's was the Atlantic green crab, a true aquatic Attila. "It eats virtually everything," Dr. Cohen said. A native of Europe, it made its North American landfall in New England, where in the 1950's it destroyed the soft-shell clam fishery. It may have been introduced here either in ballast water or, as in the case of some other species, as larvae in algae used to pack shipments of bait worms from New England.

Here, the green crab has shown itself capable of eating the Dungeness crab, a valuable food species, and there is concern that it may eliminate the Dungeness from the bay. The green crab is too small to be a marketable replacement. In Bodega Harbor, green crabs can be collected by the score. There they eat the same shellfish that are eaten by

native birds, and the concern is that the impact of the crab's depredations will cascade unpredictably through the food web.

Biological transformation has also overtaken the free-swimming creatures of the deep, open water. Gobies from Japan and shrimp from Korea, for instance, have joined the striped bass. In the fresher water of the delta at the northern end of the bay live species like goldfish, carp, threadfin shad and, from eastern North America, six species of catfish and four species each of sunfish and bass.

The economic effects of the introductions of new species have been little studied, but Dr. Cohen and Dr. Carlton say they are clearly substantial, though mixed. On one hand, according to their study, some introduced fish and shellfish have become valuable food and sportfishing species. Some, like mosquitofish, control nuisance insect populations. On the other hand, many of the exotics foul waterways and water delivery systems, damage docks, increase the cost of removing encrusting organisms from ships and prey on valuable native commercial and sport species.

Except in the Great Lakes, the Hudson River and Alaska, there are no government controls on the discharge of ballast water. Senator John Glenn, Democrat of Ohio, introduced a bill this year to extend regulations to all United States ports.

A rich ecosystem takes hold at the expense of native flora and fauna.

Even if all introductions stopped tomorrow, San Francisco Bay would hardly return to its former condition.

While the settling-out of its new ecology is not yet complete, Dr. Cohen believes it might eventually fall into a pattern similar to that observed in terrestrial areas disturbed by humans. There, a relatively few hardy, adaptable, "weedy" species that thrive on disturbance tend to take over.

Stepping back and taking a philosophical look, Dr. Carlton predicted that whatever the character of the new ecosystem, it will in time come to be accepted as natural. No matter how great a creature's impact on the bay, he said, over the years it will gradually be seen as a normal part of the environment by people who do not realize it was an immigrant.

"Three or four generations into the future," he said, "it won't be an issue. Time heals all."

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